EQUIPMENT DEVELOPMENT & TEST REPORT 5100-16

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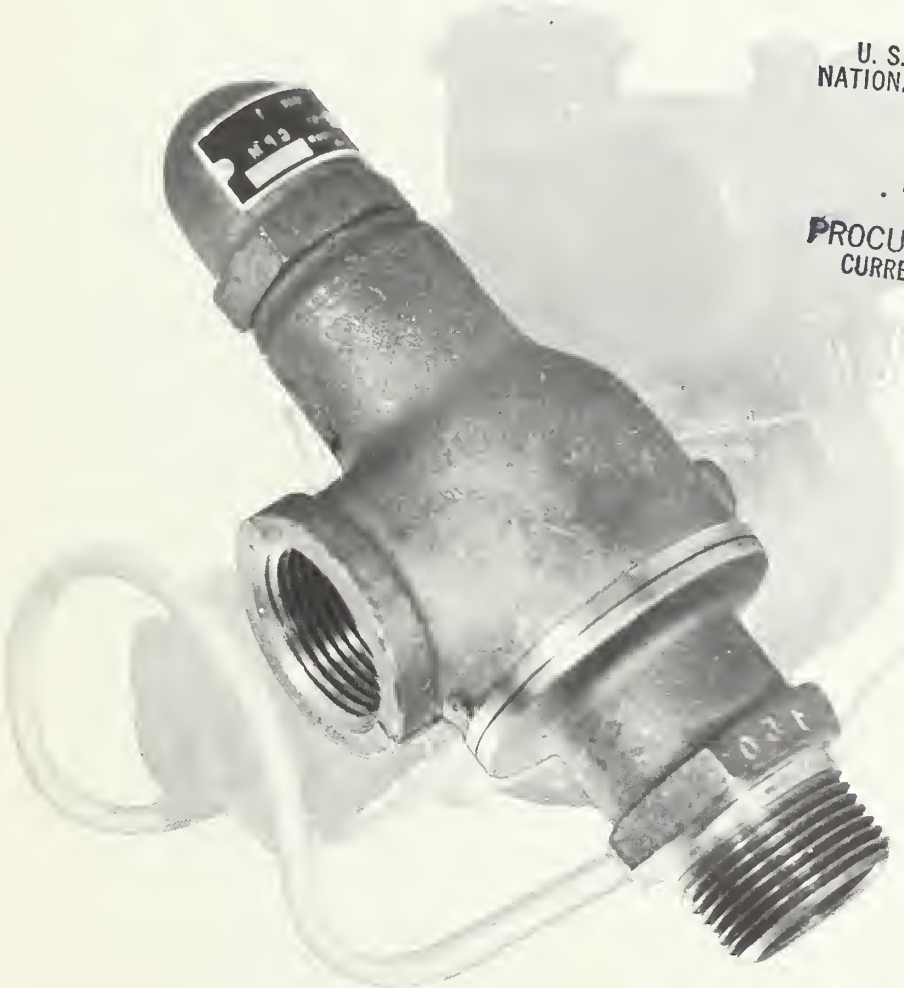

U.S. DEPARTMENT of AGRICULTURE FOREST SERVICE

EQUIPMENT DEVELOPMENT CENTER SAN DIMAS, CALIFORNIA

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EVALUATION OF PRESSURE RELIEF VALVES FOR POSITIVE DISPLACEMENT PUMPERS

ED&T 1322

by
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ABSTRACT

Every positive displacement pumper must have a pressure relief valve. The relief valve is necessary to insure that no damage will be caused to the pumper or related equipment by operating them at excessive working pressures. There are several factors which must be known and considered in order to select the best relief valve for a particular pumper. These data have not been readily available in the past; and, therefore, there have been conflicting opinions about which valves are best for the different types of pumpers.

Tests were conducted by the Equipment Development Center, San Dimas, on 16 different relief valves. The test results are discussed in detail in this report, and several graphs are included. Considerations of the results have led to the recommendation that the 1-inch-size Crane Company relief valve – factory rated for a 125-psi cracking pressure – be used on the Briggs-ECO pumper. Recommendations for relief valves to be used on several other positive displacement pumpers are presented as a Relief Valve Selection Chart. These tests also revealed that the relief valve criteria delineated in the "Engine-Driven Pumper Specification 5100-273" and "Relief Valve Specification 381" should be updated.

CONTENTS

EVALUATION OF PRESSURE RELIEF VALVES FOR POSITIVE DISPLACEMENT PUMPERS

INTRODUCTION

Tests were conducted on numerous pressure relief valves in 1966 and 1967. The valves tested were procured from five different manufacturers. Sixteen different relief valves in $\frac{1}{2}$-, 3/4-, 1-, $1\frac{1}{4}$- and $1\frac{1}{2}$-inch sizes were tested. Figure 1, showing the relief valves tested, is number-coded with Table 1, which lists the valves by size and manufacturers and gives their advertised performance characteristics and prices.

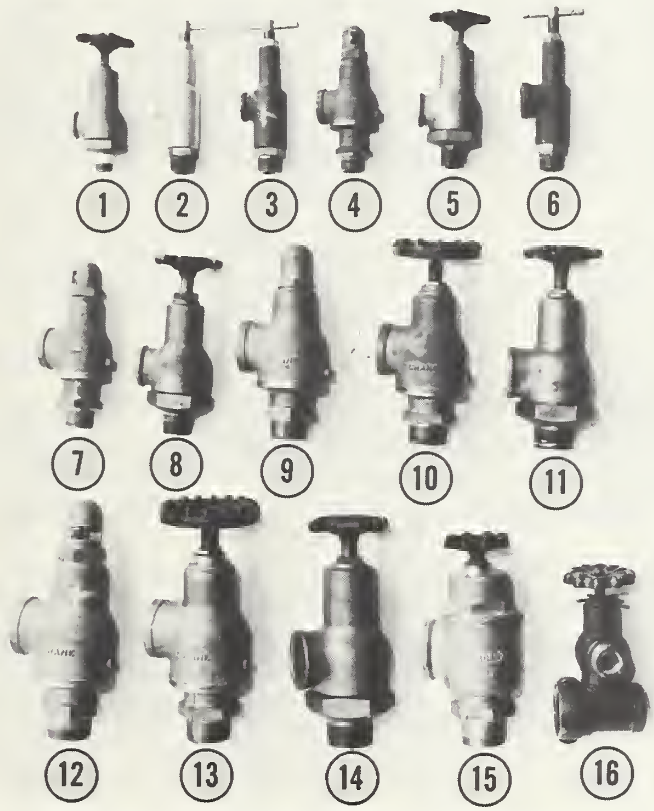


Figure 1. Relief valve test specimens

There were several reasons for conducting these tests. The principal reason was to answer questions which have arisen regarding the selection of relief valves for use with the qualified Briggs-ECO fire pumpers. It was also decided to verify that the relief valve criteria specified in the "Engine-Driven Pumper Specifications 5100-273" are correct and usable. It was further considered important to search the market for manufacturers of pressure relief valves and determine the performance characteristics of each valve which could be considered for use by the Forest Service. The intent was to select valves which have performance characteristics compatible with the various qualified positive displacement fire pumpers used by the Forest Service.

TABLE 1

LIST OF RELIEF VALVES TESTED

Valve No.	Size (inches)	Manufacturer	Type or Part No.	Cracking** Pressure (psi)	** Flow (psi)	Price (Dollars)
1	1/2	Lunkenheimer	Fig. 996	125	15	25.40
2	1/2	Spraying Systems	6815-AL-1/2 (Aluminum)	***	***	6.25
3	1/2	Spraying Systems	6815-BR-1/2 (Brass)	***	***	7.50
4	3/4	The Crane Company	2611	125	15	24.32
5	3/4	Lunkenheimer	Fig. 996	125	15	30.40
6	3/4	Spraying Systems	6815-BR-3/4 (Brass)	***	***	10.05
7	1	The Crane Company	2611	125	20	28.80
8	1	Lunkenheimer	Fig. 996	125 & 175	20	38.40
9	1-1/4	The Crane Company	2611	175	35	38.89
10	1-1/4	The Crane Company	2612	175	35	34.72
11	1-1/4	Lunkenheimer	Fig. 996	175	35	43.40
12	1-1/2	The Crane Company	2611	175	40	44.32
13	1-1/2	The Crane Company	2612	175	40	44.32
14	1-1/2	Lunkenheimer	Fig. 996	175	40	55.40
15	1-1/2	Lonergan	T.R.	175	40	37.40
16	1-1/2	Western Fire Co. *		175	40	20.00

*U.S.D.A. Forest Service Specification No. 381
**Manufacturer's advertised performance characteristic
***Manufacturer does not specify particular flow and pressure recommendations.

TESTS

The tests were conducted in the Fluid Flow Laboratory of the San Dimas Center. The relief valves which were tested are listed in Table 1 (see page 2).

The tests were designed to measure the factory setting of the cracking pressure and to determine the rate at which the relief valve discharged water when the pressure was increased incrementally beyond the cracking point. This test was also designed to determine the characteristics of the valves as the pressure was decreased incrementally until the valve was completely closed.

Valves 1 through 8 were then adjusted to relieve a specific flow and pressure. This setting was selected to simulate the performance of the Briggs-ECO fire pumper (10 gpm at 150 psi). These valves were then tested, in a way similar to that previously described, to determine their characteristics at this setting. Further tests were conducted at additional settings for selected valves, particularly the large ones. These settings simulated the WA-7 (17 gpm at 250 psi) and the WX-10 (21 gpm at 200 psi). Several additional tests were also made at settings simulating the Edwards L-23 and 120 Model fire pumpers. Again, the same procedures were followed for determining data.

For all tests, three runs were conducted on each valve so that the average cracking pressure and the average performance characteristics could be established.

DATA

Graph No. 1 is presented in Discussion (page 7). It shows the pumper's rated performance (indicated by ⊙) in output flow rate related to discharge pressure. It further shows the calculated output of the pumper when (1) a 3/4-inch Spraying Systems valve is used (indicated by ⚠) and (2) a 1-inch Crane valve is used (indicated by ⬡).

Graphs 3, 4, and 5 are presented in Appendix A. On these graphs, there are eight performance characteristics curves (of the almost 100 which were established) that were considered to be of outstanding significance. The graphs showing performance characteristics for each of the relief valves tested at each setting are on file at the San Dimas Center. Table 3 is a presentation of the test ratings for each of the relief valves tested.

Appendix B contains significant relief valve data taken during a previous slip-on tanker test.

RESULTS

The $\frac{1}{2}$- and 3/4-inch relief valves manufactured by Spraying Systems Company had two common characteristics. The first is that the cracking pressures are far below the requirements for relief valves for the Briggs-ECO pumpers. Secondly, the flow characteristics are not desirable. Ideally, a relief valve will not allow flow until the desired pressure is reached; and, when this occurs, the valve will begin to open. The valve will then continue to open at a smooth rate and become fully open at only

a small percentage increase in pressure. Graph No. 3 in Appendix A shows that the performance characteristics of these valves are far from ideal. In addition to the above characteristics, the Spraying Systems' 6815-AL $\frac{1}{2}$-inch aluminum valve did not completely close for two of the three test runs.

The $\frac{1}{2}$-, 3/4-, 1-, $1\frac{1}{4}$- and $1\frac{1}{2}$-inch relief valves manufactured by the Lunkenheimer Company exhibited several characteristics in common and others which were apparently peculiar to size. The average cracking pressure fell within 1 psi of the desired cracking pressure for all of the sizes tested. Therefore, Lunkenheimer valves are considered to be very good as far as cracking pressure is concerned. The valves also exhibited good flow characteristics. That is, the output flow rate increases very rapidly as pressure increases above the cracking point. There is, however, a peak in most of the flow curves which occurs just after the cracking pressure is reached. This peak is caused by the pressure increasing rather sharply with flow and then decreasing slightly as the flow continues to increase. The most unfavorable characteristic of the Lunkenheimer valves was that several of the sizes tested vibrated and emitted a loud squeal when the valve was relieving low flows. The vibration and noise were accompanied by pulsating output flow. Recently, the San Dimas Center conducted performance tests on a slip-on tanker which was equipped with a $1\frac{1}{4}$-inch Lunkenheimer relief valve. After about 4 hours of testing, this valve was discarded because of the increasing noise and pressure and flow fluctuation. Inspection of the valve and valve seat showed signs of damage from impaction.

The 3/4-, 1-, $1\frac{1}{4}$-and $1\frac{1}{2}$-inch Type 2611 Crane Company relief valves all had cracking pressures which were relatively constant for each test setting. They also exhibited generally good performance characteristics. It is interesting to note that the 1-inch Crane relief valve performed well at all settings. The factory setting (125 psi) gave an average cracking pressure of 133 psi and relieved 10 gpm at 149 psi and 15 gpm at 150 psi. When set to relieve 17 gpm at 250 psi, the valve cracked at 230 psi. When set for 21 gpm at 200 psi, it cracked at 181 psi. These valves closed at a pressure only slightly lower than the cracking pressure.

The $1\frac{1}{4}$-and $1\frac{1}{2}$-inch Crane Company Type 2612 relief valves appear to exhibit characteristics similar to the Type 2611 relief valves in comparable sizes. This is to be expected, since the only physical difference is that the Type 2611 has a cap over the adjusting mechanism, while the Type 2612 has a handwheel for adjustment. The only notable difference is that the Type 2612 valves repeated cracking pressures and performance characteristics slightly more consistently than the Type 2611 valves. This difference probably is due to the fact that only one valve of each type was tested. The average performance for several valves of each type should be similar.

Further tests were conducted on additional Crane 1-inch-size relief valves. Several valves were checked to determine if performance is consistent from one valve to another. Valves with springs rated for 175 psi cracking pressure were also tested to determine what difference, if any, this makes in performance. In general, performance was good with the 175-psi springs. However, it was found that the springs supplied for a 125-psi cracking pressure performed better, at all of the settings recommended in Table 2 (page 10) than did the high-pressure spring. In some cases, vibration was noted with these valves, and sometimes less desirable performance was

obtained. Even though some of these 1-inch Crane valves did not perform as well as the first sample tested, this valve is still considered best for its recommended applications in Table 2.

The $1\frac{1}{2}$-inch Lonergan relief valve performed well; however, it produced pulsating flows, vibration, and noise very similar to the Lunkenheimer valves.

The $1\frac{1}{2}$-inch Forest Service Specification 381 valve sold by Western Fire Equipment Company had rather unusual characteristics. The valve in all cases opened very slowly for pressure increases from 3 to 20 psi above the cracking point, depending upon the pressure setting. At this point the valve was normally relieving 1 to 2 gallons per minute. Then the valve instantly opened fully, relieving from 15 to 27 gallons per minute. For all tests the pressure dropped several psi when this occurred. Other noteworthy characteristics were observed when tests were conducted to determine closing pressures. The pressure and flow both gradually decreased at a constant rate until a flow of from 8 to 11 gallons per minute was being relieved. The valve would then close instantly. This occurred at pressures as low as 60 psi below the cracking pressure. Both the instantaneous opening and closing are undesirable, since they generate pressure surges. The extremely low closing pressures and constant valve leakage are also undesirable characteristics.

Although none of the relief valves tested performed ideally in all respects, Table 2 lists valves that are acceptable for use on present qualified positive displacement pumpers.

TABLE 2

RELIEF VALVE SELECTION CHART

Briggs-ECO Pumpers Edwards - Model EBE Western Fire - 14 x 120A Pacific Pumpers - Model BE	
Desired Cracking Pressure (minimum)	125 psi
Rated Pumper Output	11 gpm @ 150 psi
Alternate Pumper Rated Output	10 gpm @ 150 psi
3/4-inch Crane Company Type 2611 or Type 2612 (125 psi spring)	
1-inch Crane Company Type 2611 or Type 2612 (125 psi spring)	
Pacific Pumper Model WX-10	
Desired Cracking Pressure (Minimum)	175 psi
Rated Pumper Output	21 gpm @ 200 psi
1-inch Crane Company Type 2611 or Type 2612 (125 psi spring)	
1-1/4 inch Crane Company Type 2611 or Type 2612 (175 psi spring)	
Pacific Pumper Model WA-7 Pacific Pumper Model WA-8 Pacific Pumper Model GA-8 Pacific Pumper Model TSA-8	
Desired Cracking Pressure (Minimum)	220 psi
Rated Pumper Output	17 & 18 gpm @ 250 psi
1-inch Crane Company Type 2611 or Type 2612 (125 psi spring)	
1-1/4 inch Crane Company Type 2611 or Type 2612 (175 psi spring)	
Edwards Model L-23	
Desired Cracking Pressure (Minimum)	175 psi
Rated Pumper Output	28 gpm @ 200 psi
1-1/2 inch Crane Company Type 2611 or Type 2612 (175 psi spring)	
1-1/4 inch Crane Company Type 2611 or Type 2612 (175 psi spring)	
Edwards 120	
Desired Cracking Pressure (Minimum)	220 psi
Rated Pumper Output	35 gpm @ 250 psi
1-1/2 inch Crane Company Type 2611 or Type 2612 (175 psi spring)	

DISCUSSION

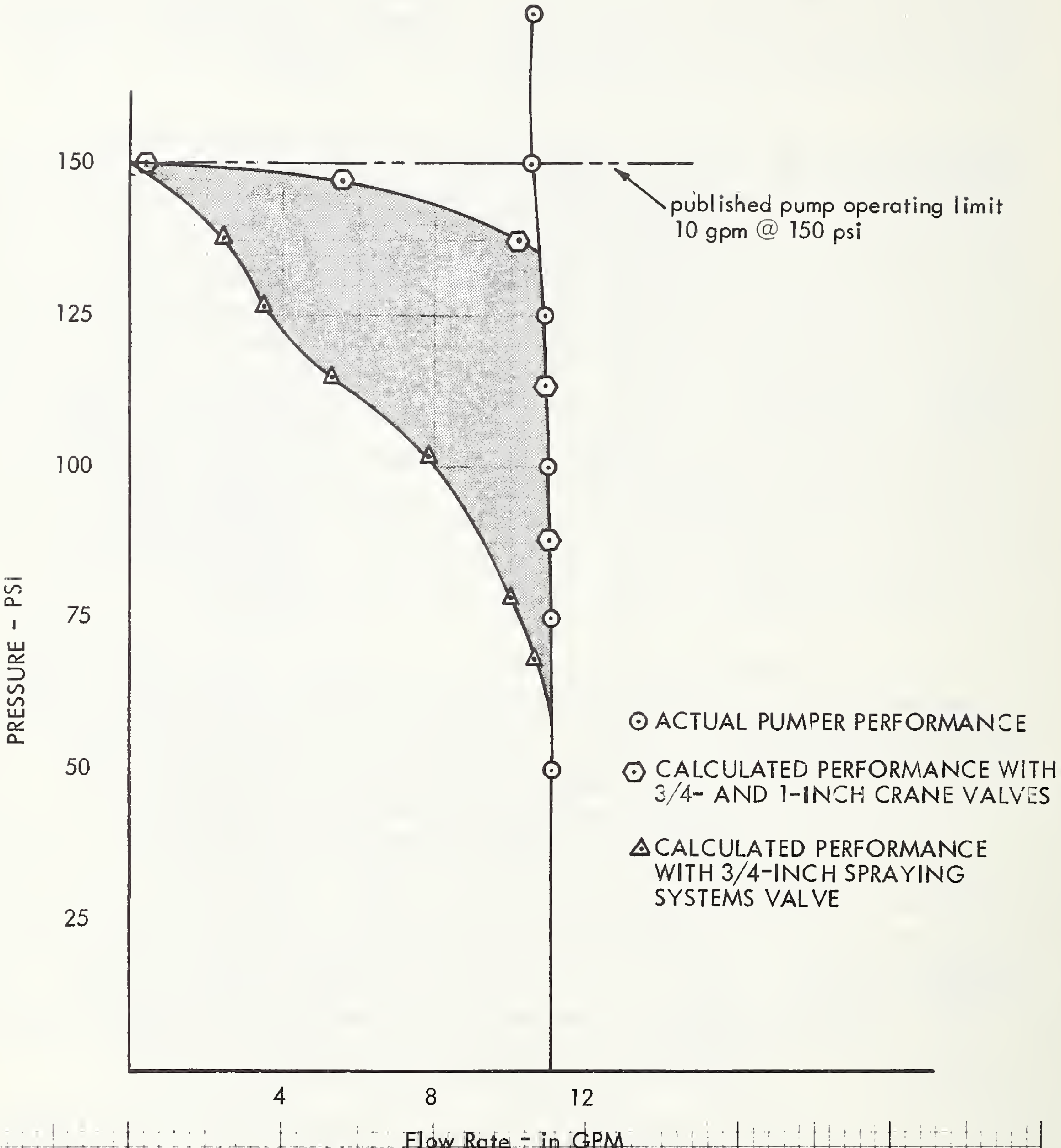
It is very important to select the proper relief valve to do a particular job, since they are designed and sized to perform correctly when subjected to some specific maximum flow and pressure. A valve must be selected to protect the positive displacement pumper and its related systems. That is, the full output of the pumper must be bypassed at some pressure slightly below the pumper's maximum operating conditions if protection is to be achieved.

However, there is another very important factor. Pumpers are purchased for certain performance characteristics. These characteristics are defined by a curve relating output flow rates to different operating pressures. An inadequate relief valve may begin opening at some pressure considerably below the maximum pump pressure, thus bypassing some of the flow that would otherwise be delivered to the fire nozzle. This is dramatically illustrated in Graph No. 1. It can be observed that, for every operating pressure above approximately 60 psi, more flow is delivered from the system which uses the Crane valve than from the one which uses the Spraying Systems valve. For example, at 115 psi the system using the Crane valve delivers the full output of the pumper (about 11 gpm), while the one using the Spraying Systems valve delivers only about 4 gpm. Graph No. 1 was the basis for Graph No. 2, which is the more practical rendering of the results. Pressures have been converted to their elevation equivalents and, as such, represent the nozzle being higher than the pump. Flow has been plotted as a decreasing function rather than an increasing one; and, thus, the flow may be seen to decrease as the elevation increases. Friction losses are neglected on this graph, as the many possible slopes which occur all give different results since the length of hose must be different.

The reason for determining the bypassed flow rate as a function of decreasing pump pressure from some maximum to a lower working pressure may be somewhat obscure. An increasing pressure situation is equivalent to increasing the elevation difference between the pump and the nozzle. Less obviously, it is also analogous to closing the nozzle, which increases the pressure the pump and relief valve "feel". The decreasing pressure situation, as shown by dashed lines on Graph No. 5, Appendix A, shows what occurs when the nozzle has been closed for some reason and then opened. This condition occurs very often in field practice, which is the reason for determining this valve characteristic. Even though a relief valve is found to open at some pressure only slightly below the operating pressure and otherwise exhibits good performance characteristics, it is not necessarily a good valve. It must also close at a pressure very near to that at which it opened. If the valve does not close until a much lower pressure is reached, it may greatly limit the pumper's capability in the situation described above by bypassing a part of the pump flow required at the nozzle.

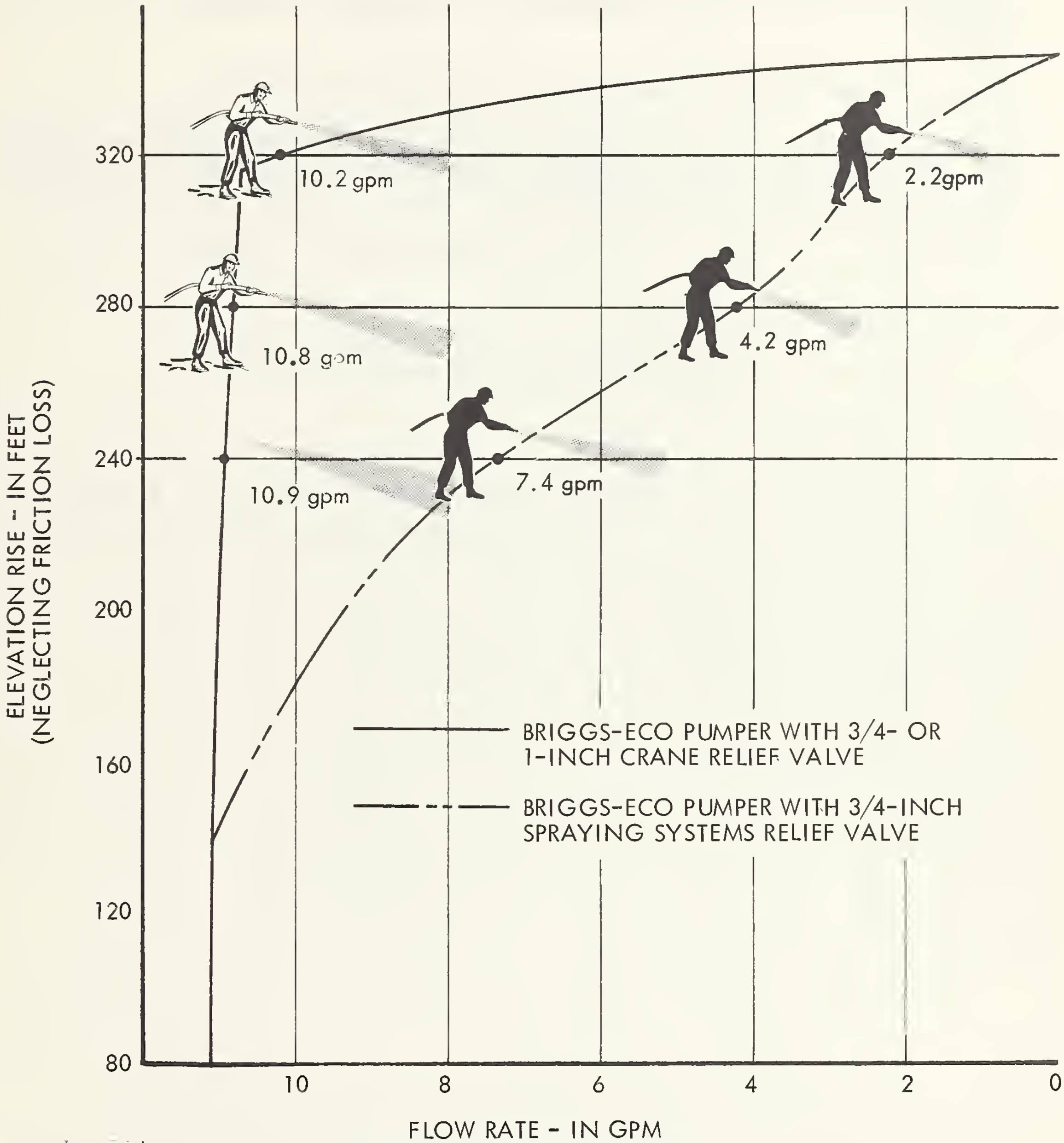
Appendix B contains some additional important relief valve information which was obtained during a previous test of a slip-on tanker. This test consisted, in part, of determining the performance characteristics of the tanker when some minor modifications were made to the plumbing. Graphs No. 6 and No. 7, in Appendix B, show the tanker output with the different plumbing situations used during tests with the Pacific Pumpers Inc. and Model WX-10 and WA-7 pumpers. These graphs show that the changing of relief valves drastically affected the performance of both of these pumpers.

GRAPH NO. 1



BRIGGS-ECO PUMPER PERFORMANCE
REDUCED BY DIFFERENT RELIEF VALVES

GRAPH NO. 2



BRIGGS-ECO PUMPER PERFORMANCE
RELATED TO ELEVATION RISE

CONCLUSIONS

The 3/4- and 1-inch Crane relief valves were the only ones tested that meet the requirements for use on the Briggs-ECO pumper. From further test data it can be concluded that the 1-inch Crane valve will also perform well on certain larger pumpers.

None of the relief valves tested performed ideally in all respects.

A particular relief valve when purchased and used in the field might perform quite differently from those which were tested. Statistically, this is to be expected because of manufacturing variances.

APPENDICES

CONTENTS

Appendix A - Results of Pressure Relief Valve Tests

Appendix B - Selected Portions of An Evaluation of a 200-Gallon Fiberglass "Slip-On" Tanker

APPENDIX A

RESULTS OF

PRESSURE RELIEF VALVE TESTS

TABLE 3

RESULTS OF CRACKING PRESSURE AND PERFORMANCE TESTS

Valve No.	Cracking Pressure psi	Performance Characteristics gpm	psi	
1	124	10	139	(1)
	124	15	138	
2	88	10	140	(2) (4)
3	92	10	140	(4)
4	124	10	150	
	220	17	250	(4)
	169	21	200	(4)
5	124	15	142	(3)
		10	142	
6	60	10	150	(4)
	126	17	250	(4)
	58	21	200	(4)
7	133	10	150	
	133	15	150	
	230	17	250	(4)
	181	21	200	(4)
8	125	20	134	
	125	15	135	(1) (3)
9	186	35	230	
10	176	37	225	
11	175	35	175	(1)
12	172	40	206	
	215	17	250	(4)
	165	21	200	(4)
13	175	40	211	
14	175	40	180	
15	173	40	201	
16	135	16	140	
	242	30	250	
	175	24	200	

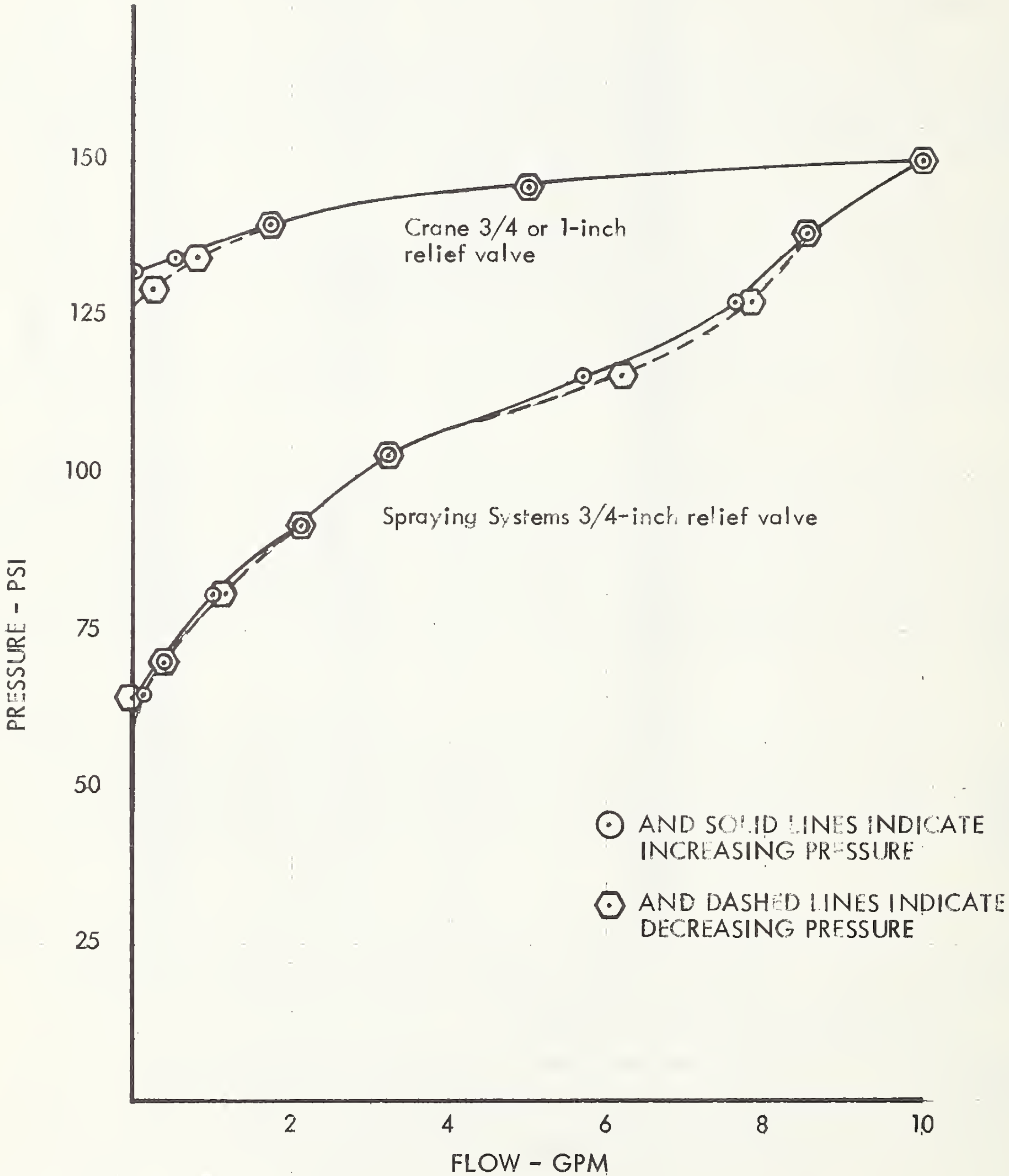
(1) At low flows, the pressure rose quickly to above the rated pressure and then decreased to the rated pressure.

(2) On two of the three test runs, the valve did not completely seat.

(3) The valve squealed and emitted a pulsating flow at several ranges of flow.

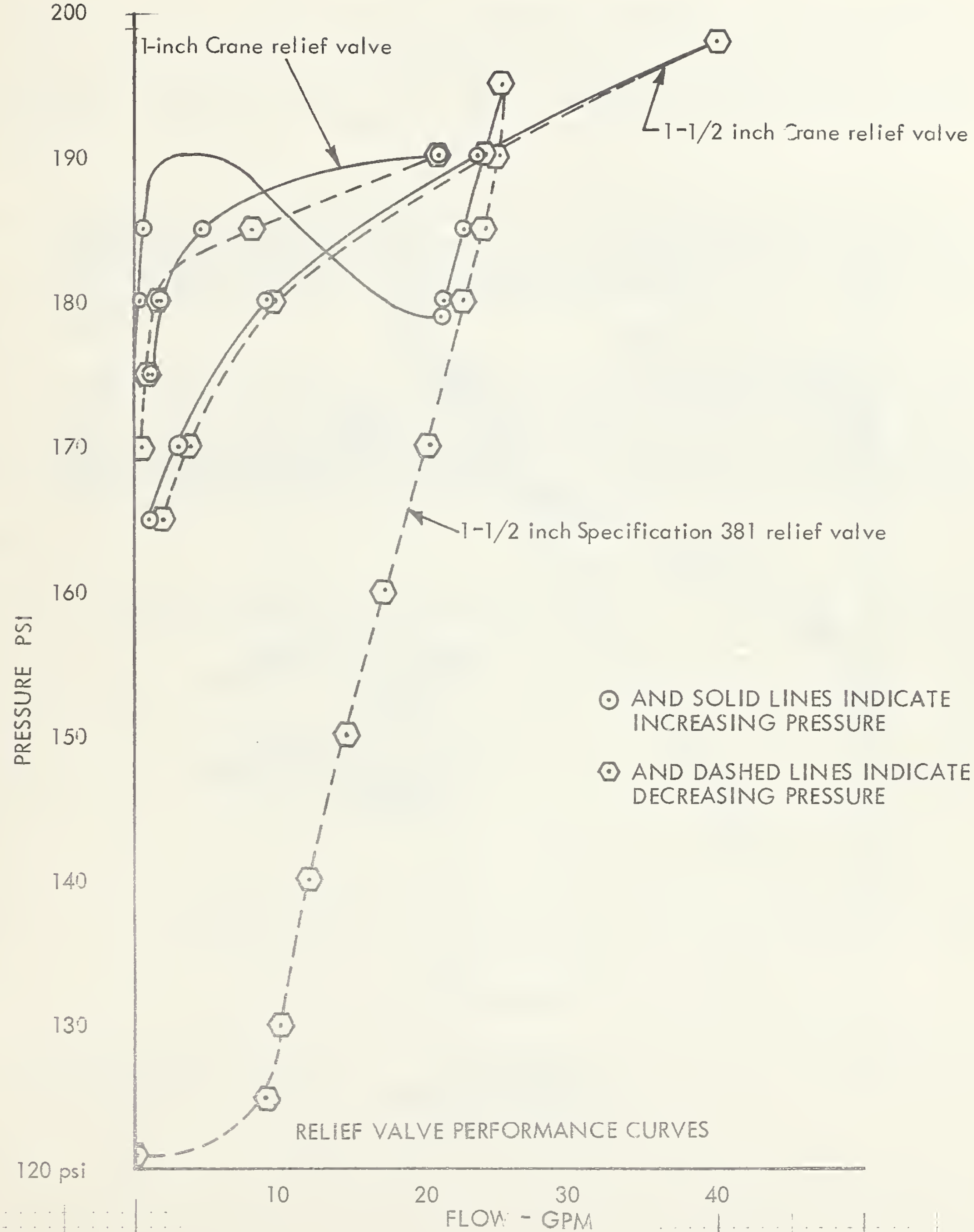
(4) The valve was set to produce this flow and pressure.

GRAPH NO. 3

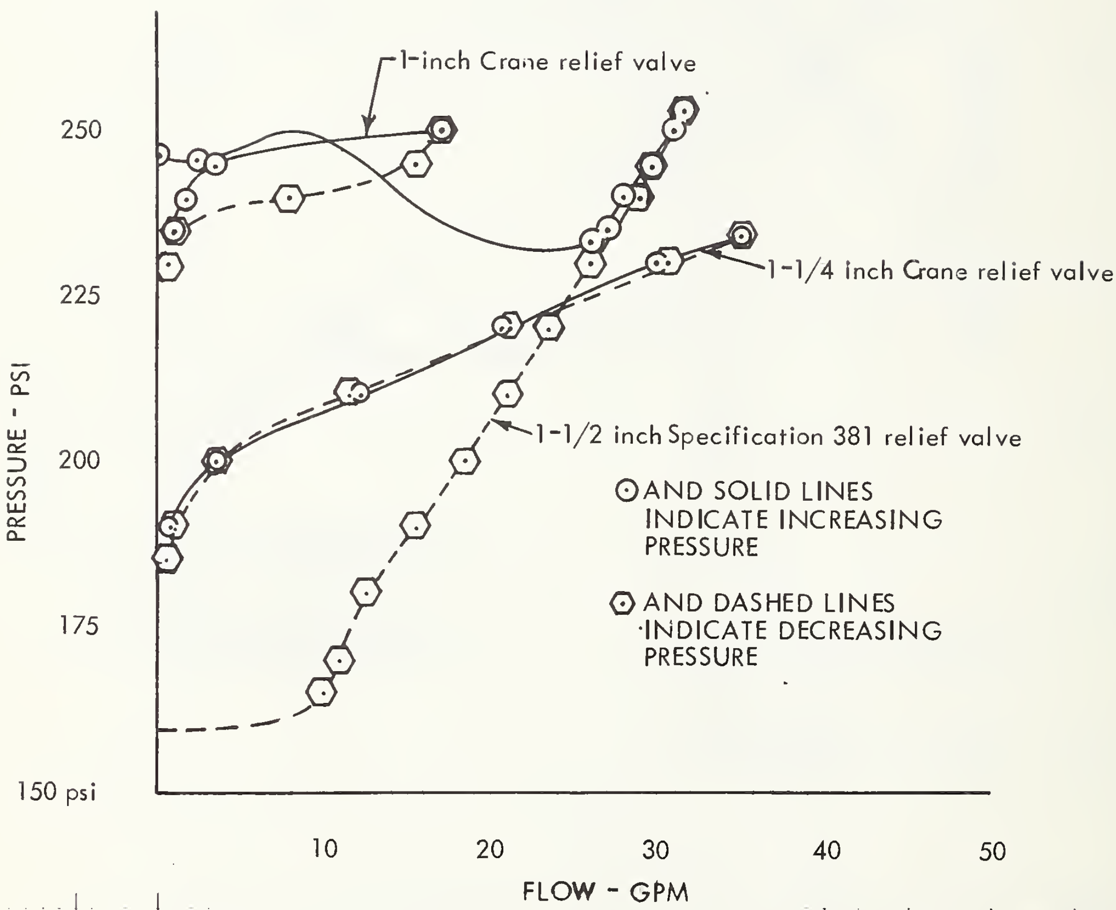


RELIEF VALVE
PERFORMANCE CURVES

GRAPH NO. 4


200
190
180
170
160
150
140
130
120 psi
PRESSURE PSI
1-inch Crane relief valve
1-1/2 inch Crane relief valve
1-1/2 inch Specification 381 relief valve
AND SOLID LINES INDICATE INCREASING PRESSURE
AND DASHED LINES INDICATE DECREASING PRESSURE
RELIEF VALVE PERFORMANCE CURVES
10
20
30
40
FLOW - GPM

GRAPH NO. 5



RELIEF VALVE
PERFORMANCE CURVES

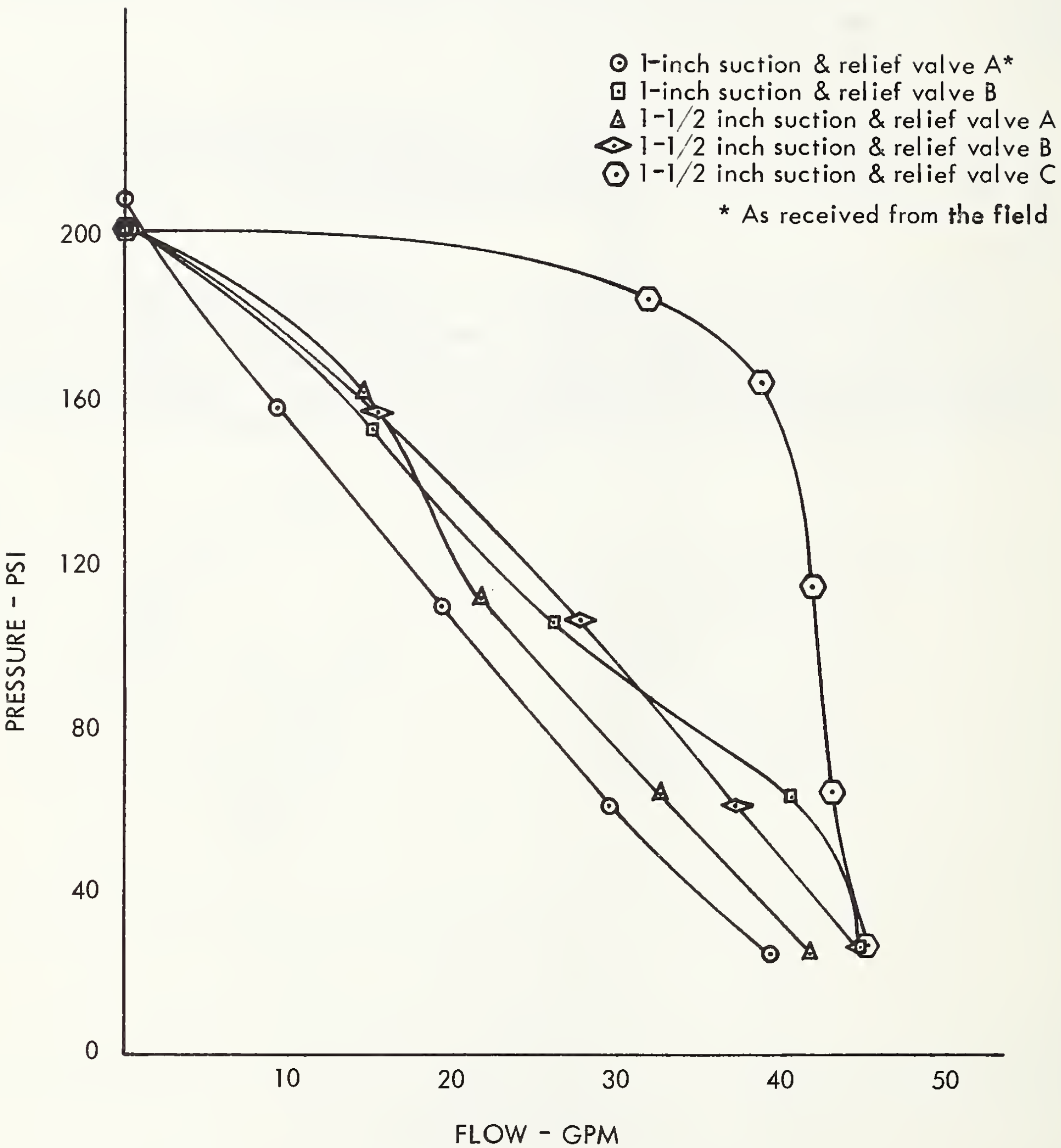
APPENDIX B

Selected Portions of an Evaluation of a 200-Gallon Fiberglass "Slip-on" Tanker

During fiscal years 1966 and 1967, a 200-gallon fiberglass "slip-on" tanker was tested at San Dimas. Portions of this test involved using different pumpers with various combinations of plumbing and pressure relief valves in an attempt to improve performance. Significant results of this test as concerned pressure relief valves are included in this appendix. These include two graphs and the following brief quotation:

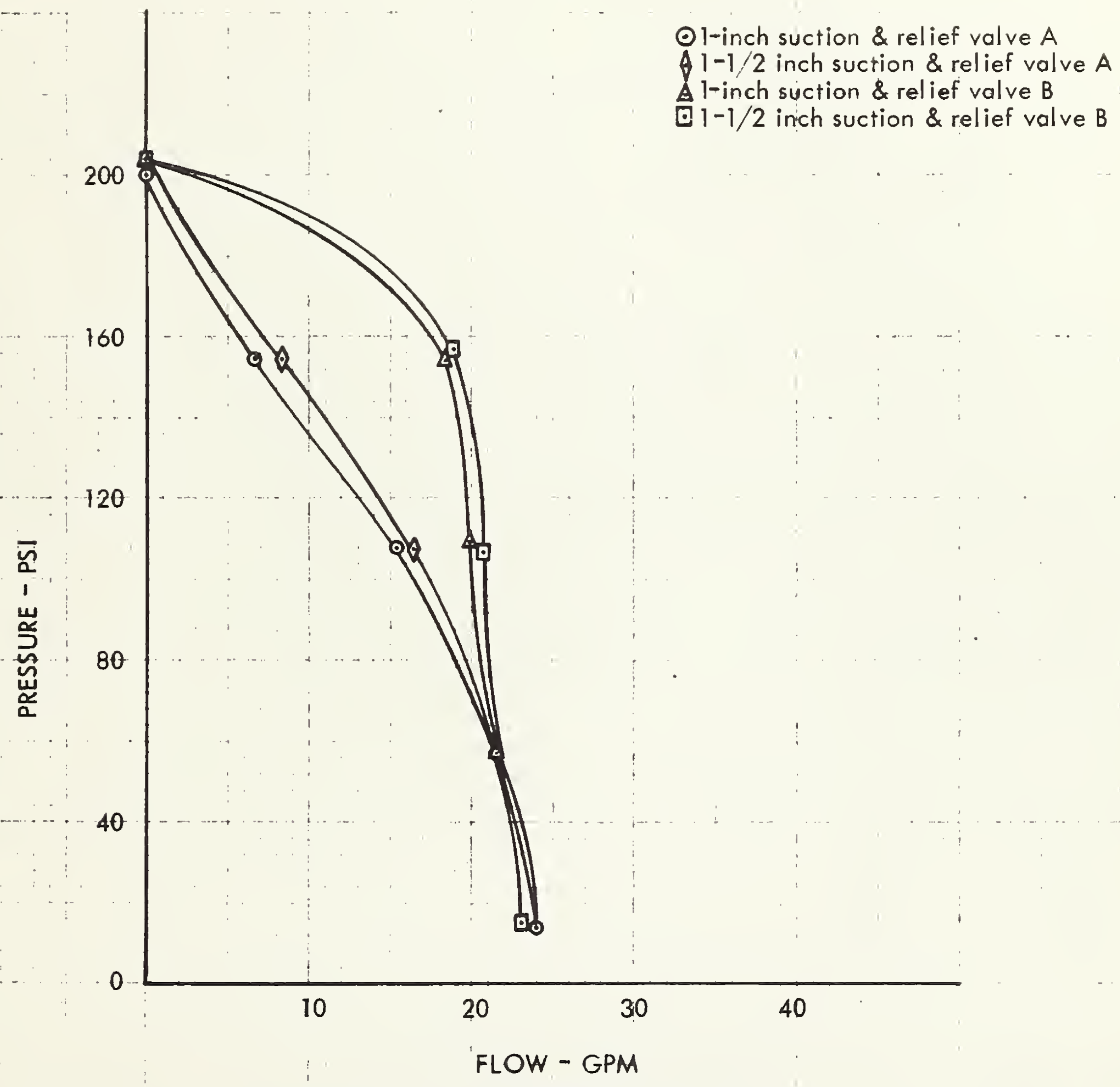
> The graphs also show that the performance of the pumper can be greatly improved by changing the pressure relief valve. It can be seen that the performance of the WX-10S pumper was increased by at least 300 percent in the pressure range of 140 to 198 psi by using a Crane $1\frac{1}{4}$-inch relief valve and a $1\frac{1}{2}$-inch suction line.
>
> An important result shown by the graphs is that the smaller and less expensive (40 lbs. lighter, $50.00 cheaper) WA-7S pumper could be made to perform better (when an appropriate relief valve was used) over the normal operating pressure range 120 to 200 psi than the WX-10S pumper, equipped with the Spraying Systems Model 6815-BR-3/4 relief valve, as received from the field.

GRAPH NO. 6



WX-10S PUMPER PERFORMANCE CURVES

GRAPH NO. 7



WA-7S PUMPER PERFORMANCE CURVES

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FOREST SERVICE

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